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IWR INSTITUTE FOR WATER RESOURCES

DESIGN OF AN APPROACH TO ESTIMATING FLOOD DAMAGE TO ROADS

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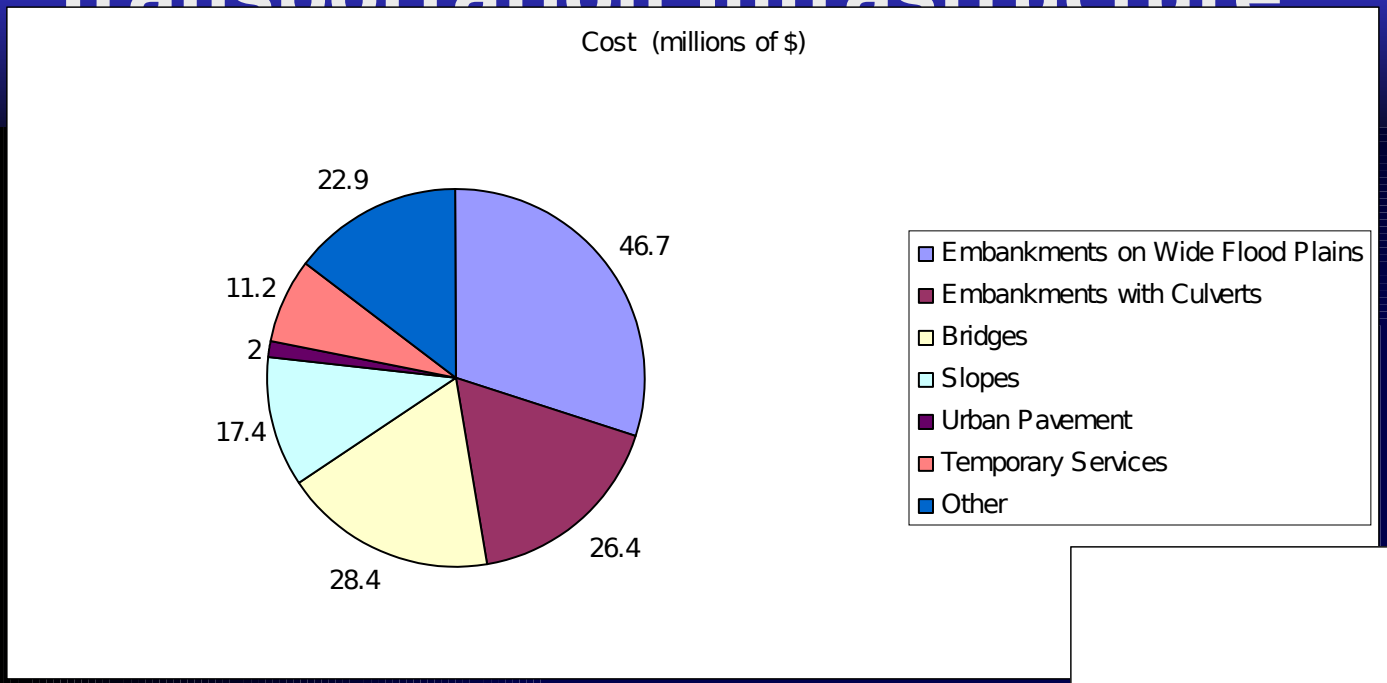
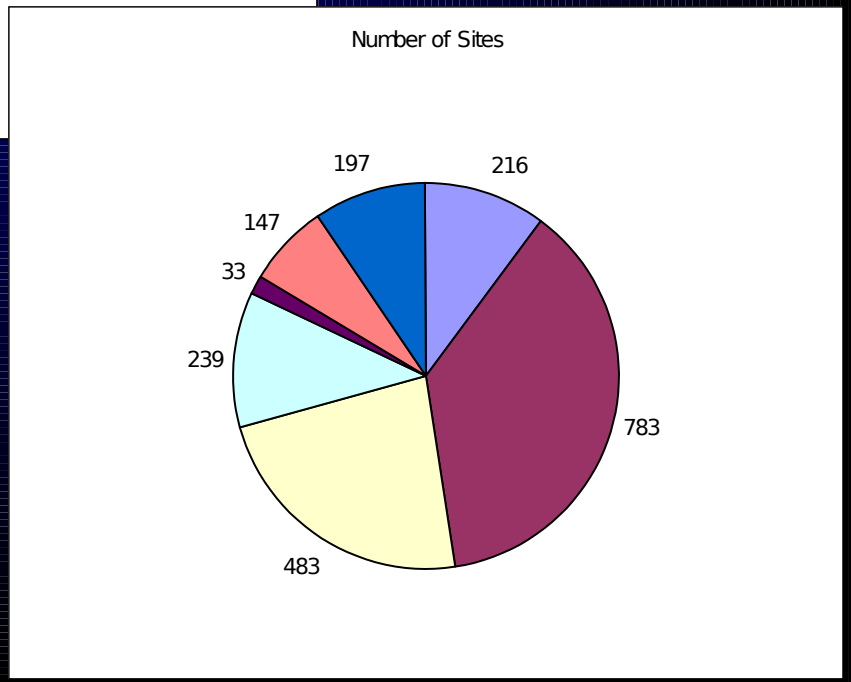
Significant Public Costs of Flood Damage to Transportation Infrastructure

1993 Upper Mississippi Flood



Type	Cost (millions of $)	Number of Sites
Embankments on Wide Flood Plains	46.7	216
Embankments with Culverts	26.4	783
Bridges	28.4	483
Slopes	17.4	239
Urban Pavement	2	33
Temporary Services	11.2	147
Other	22.9	197



Overview

- Goal: Include routine analysis of costs related to flood damage to roads in FDR studies
  - Standardization of approaches / elements
    - Various current levels of detail and analysis techniques
  - Appropriately capture benefits of FDR projects
  - Incorporation into Corps planning tools and models
    - Certifiable models
- IWR Initiatives
  - Review of Practice (RS Means, 2001)
  - Statistical Model (BMA, 2006)
  - Design Document (2008)
  - Proof of Concept / Prototype Tool Development (late 2008)
- Present the Proposed Approach and Framework
- Obtain Feedback from Field

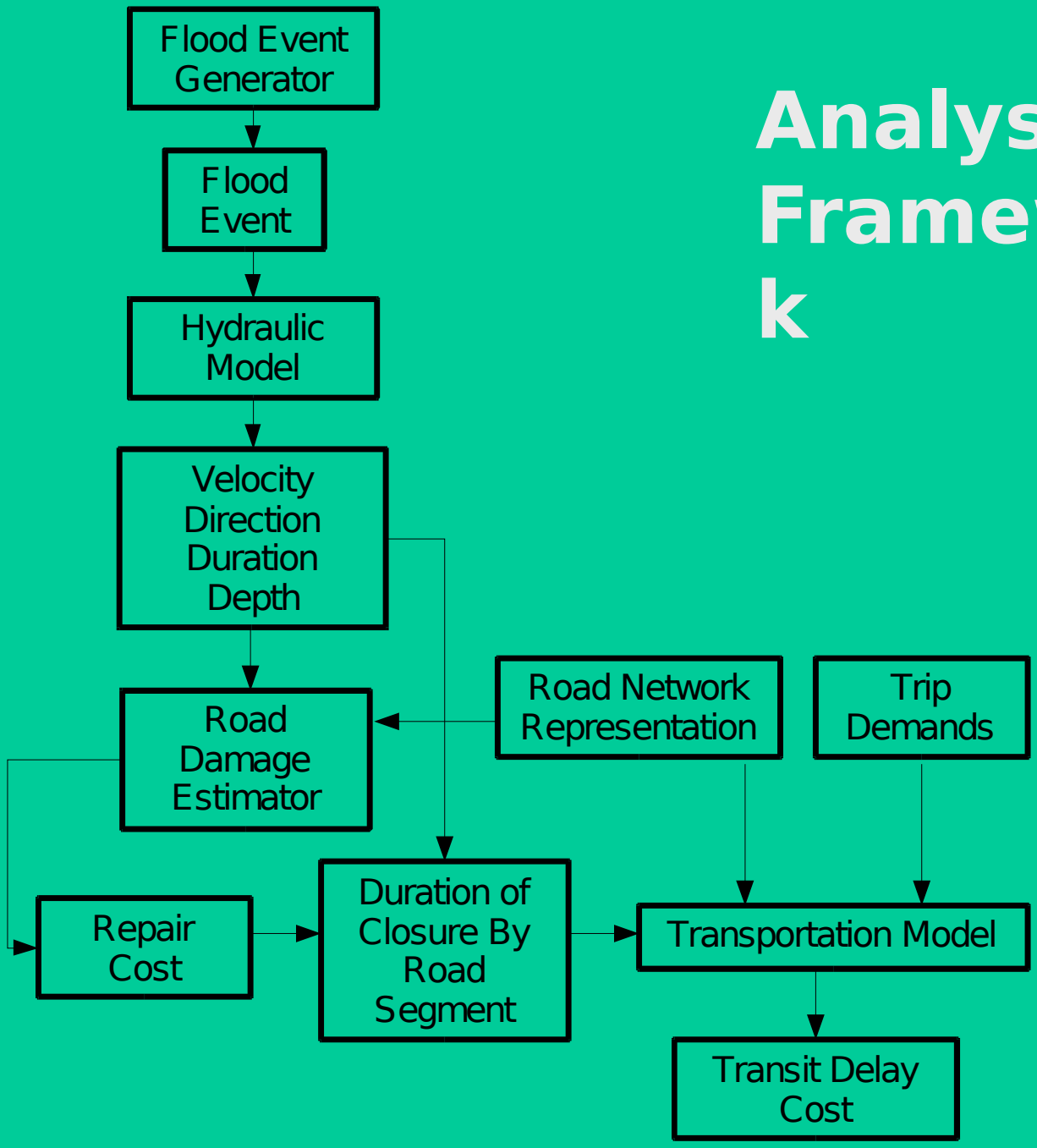
Design Document

- Analysis Framework
  - Spatial / GIS
  - Existing Hydraulic and Flooding models
  - Transportation Modeling
- Prior / Related Work
- Issues
  - Lack of widely applicable damage functions (and supporting data)
  - Complexity of consequence assessment (transit delay)

Key Concepts

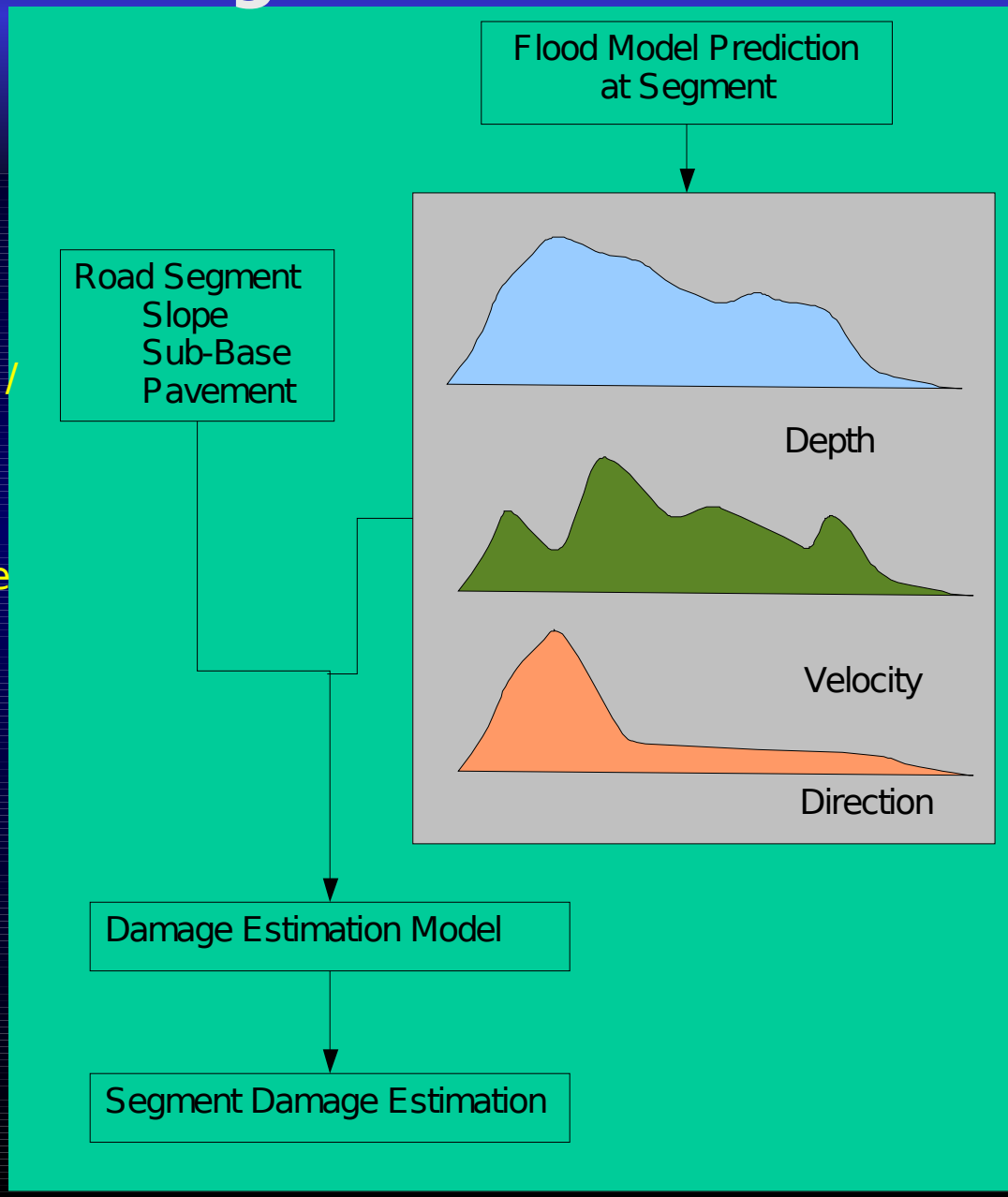
- Segment
  - Individual portions of roadway
  - May be closed / damaged by flood
  - Costs
    - Post-flood inspection
    - Direct repair / cleanup
- Network
  - Transportation system as a whole
  - System effects due to closure of segments
  - Costs
    - Traffic Delay (period of inundation, period of construction)
      - Longer routes, greater congestion
    - Increased accident / loss of life costs

Analysis Framework

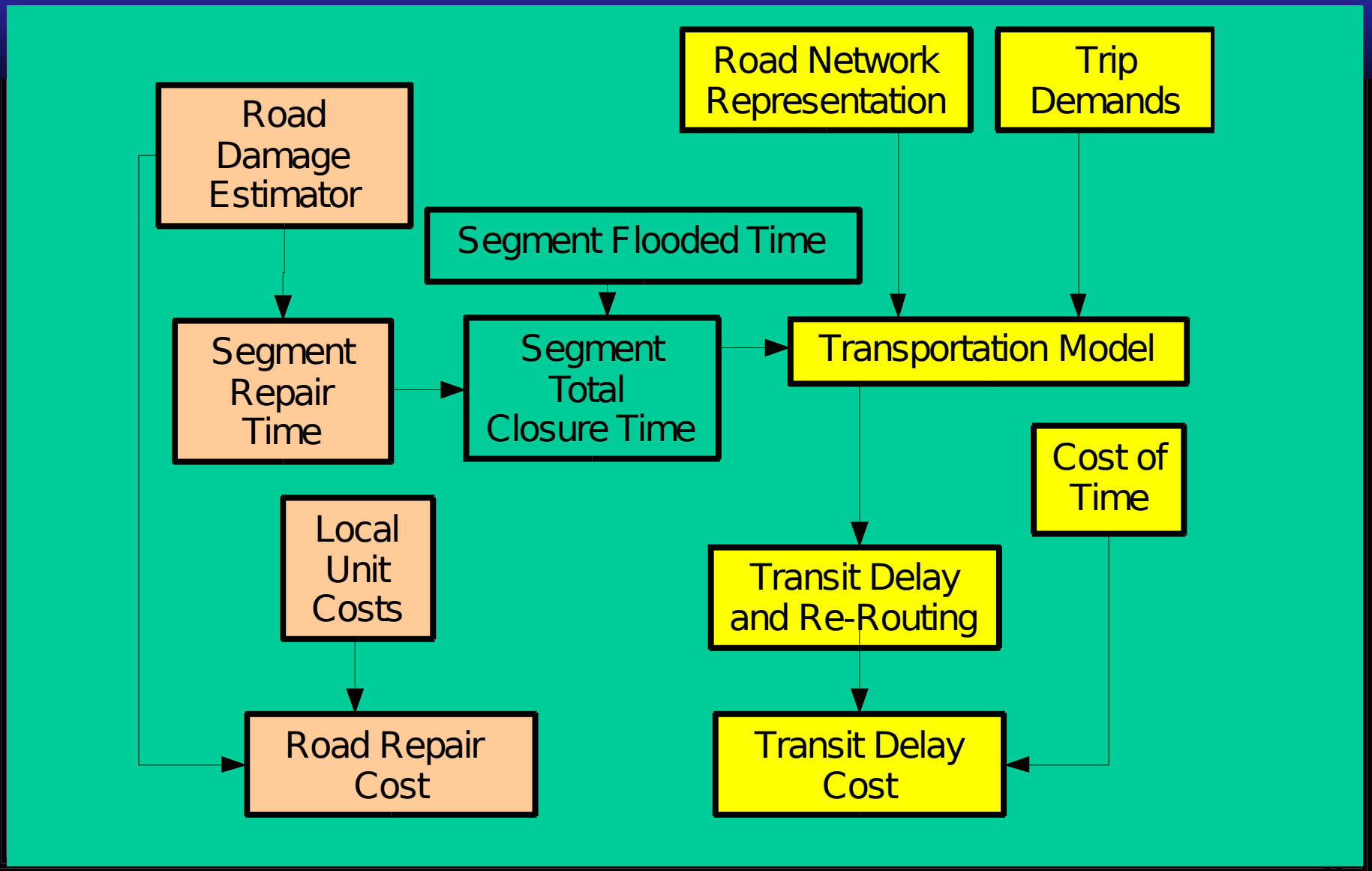


Flood Event at Road Segment

- Road Segment
  - Uniform physical characteristics / value
  - Uniform flood impacts
- Flood hydrograph at road segment
  - Velocity / Duration / Direction / Depth
- What are the damage impacts:
  - Cost and Duration of Damage Repair
  - Duration of Overtopping
  - Duration of Repair



Network Impact



Prior and Related Work

- RS Means Survey of Practice
- BMA Statistical Model
- FHWA Hydraulic Engineering Circular 17
- Corps Studies using Transportation Models
  - Des Plaines
  - Mill Creek

Estimating The Repair Costs To Flood-Damaged Roads, RS Means (2001)

- Interviews with 15 Corps personnel
  - 50 surveys sent out (majority economists)
  - 58% of respondents see need for more standardization
- Costing data used primarily in
  - Feasibility reports / Continuing authority projects / Reconnaissance reports
- Gross level data
- Cost estimates
  - Rebuilding costs / NOT retrofit costs to increase road stability
- Cost estimating sources
  - Local Transportation Departments / Engineers
  - Bid-based data not practical
  - Detailed cost estimating data not practical

“Most often the true extent of damages are not realized until months after the flood event occurs. It is very difficult to assess the ‘true’ impact of flooding for roadways because of the … delayed impact of flooding on roadways and the lack of detailed repair cost data”

R.S. Means survey response, Lee Robinson

BMA Engineering, Methodology for Developing Predictive Models for Flood Damage to Roads (2006)

- Roads only, not bridges
- Multivariate linear model
  - Type of road
  - Parameters of the flood
- Estimates Damage ratio
  - flood damage per unit length of roadway / new construction cost per unit length of the roadway
- Does not estimate duration of outage for repair
- Statistical, not causal
- Example using 136 events from 7 states
  - Missouri, Nevada, Texas, Kansas, Iowa, Illinois, and Colorado

BMA Engineering: Characterization / Variables / Categorization

- Floodwater Speed
  - None to low
  - Medium
  - High
- Floodwater Direction
  - Parallel
  - Oblique
  - Perpendicular
- Flood Duration
  - < 24 hours
  - 24-28 hours
  - > 48 hours
- Depth of Inundation
  - < 2 feet
  - 2 –4 feet
  - > 4 feet

- Roadway Slopes
  - Grass
  - Clay and rock
  - Rock and gravel
  - Silt, sand and gravel
  - Silt and Sand
- Roadway Sub-base Type
  - Concrete slope protection
  - Asphalt slope protection
  - Grass
  - Clay & rock
  - Rock and gravel
  - Silt/sand and gravel
  - Silt and sand
- Pavement Type
  - Asphalt
  - Concrete

BMA Engineering: Coding Scheme

Case Number	Case ID	Velocity	Direction	Duration	Depth	Slope	Sub-base	Material roadway	Damage Fraction
1	CO-1	2	3	1	1	3	1	2	0.1
2	CO-2	2	3	1	2	3	1	2	0.1
3	CO-3	2	3	1	2	3	1	2	0.1
4	IA-1	3	3	2	2	6	4	2	1
5	IA-2	2	3	2	1	3	4	2	0.35
6	IA-3	2	3	2	2	4	2	2	0.26
7	IA-4	3	3	2	3	3	4	2	1
8	IA-5	3	3	2	2	2	3	2	0.76
9	IA-6	3	3	2	2	2	2	2	0.73
10	IA-7	3	3	2	2	2	4	2	0.49
11	IA-8	3	3	2	2	6	2	2	0.9
12	IA-9	3	3	2	2	2	2	2	0.47
13	IA-10	3	3	2	2	2	2	2	0.31
14	IA-11	3	3	2	2	2	2	2	0.28
15	IA-12	3	3	2	2	2	2	2	0.5
16	IA-13	3	3	2	2	2	2	2	0.37
17	IA-14	2	1	2	2	6	4	2	0.09
18	IA-15	2	1	2	2	6	4	2	0.06
19	IA-16	2	3	2	2	2	4	2	0.12

BMA Engineering: Results

- Most important explanatory variables
  - Flood flow direction relative to roadway centerline
  - Roadway slope
  - Floodwater speed
  - Sub-base Type
- Removed from model
  - Duration
  - Depth
  - Roadway Material

Damage ratio = −1.135 + 0.279 * Speed + 0.169 * Direction + 0.077 * Slope + 0.064 * Sub-base

$R^2 = 0.518$

HEC-17: The Design of Encroachments on Flood Plains Using Risk

- Risk-based Design Approach

  "Instead of one water surface profile, the LTEC design process requires water surface profiles for each discharge for existing conditions and for each alternative design condition"

- Transportation Delay Cost

  "A major part of the economic losses due to inundation of a stream crossing involve traffic termination and delays caused by the need to detour traffic to an alternate route or routes."

- Empirical Cause-based Damage Estimation

- Complete Analysis Procedure

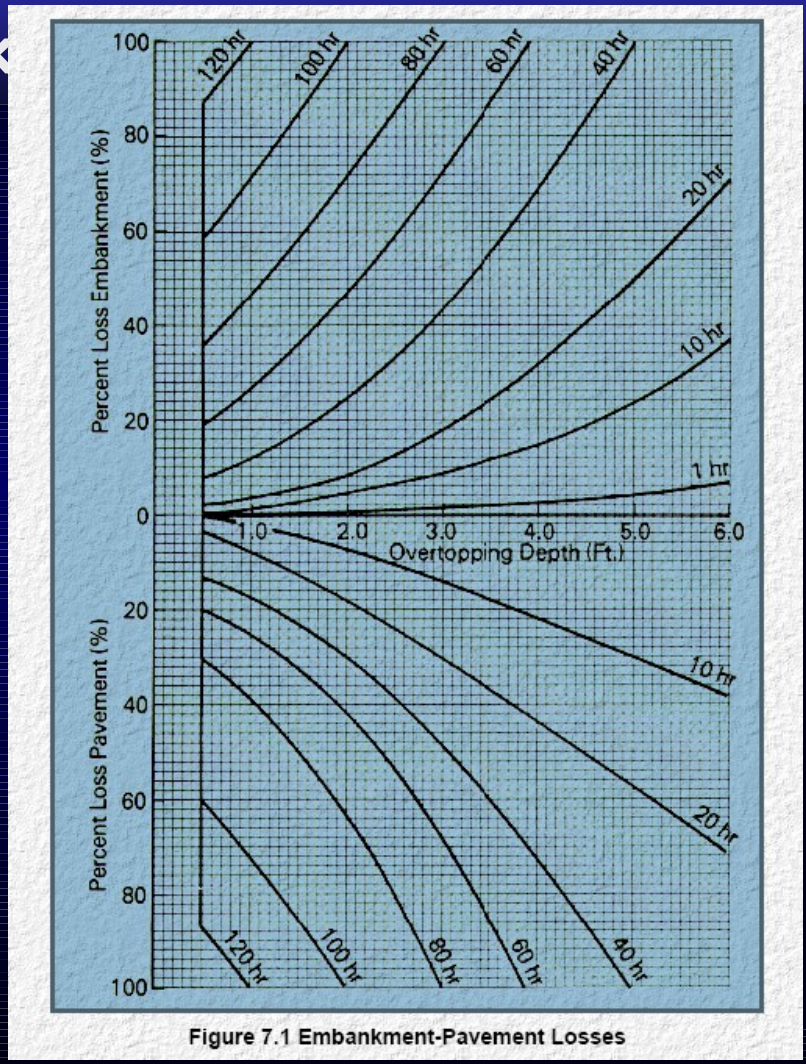
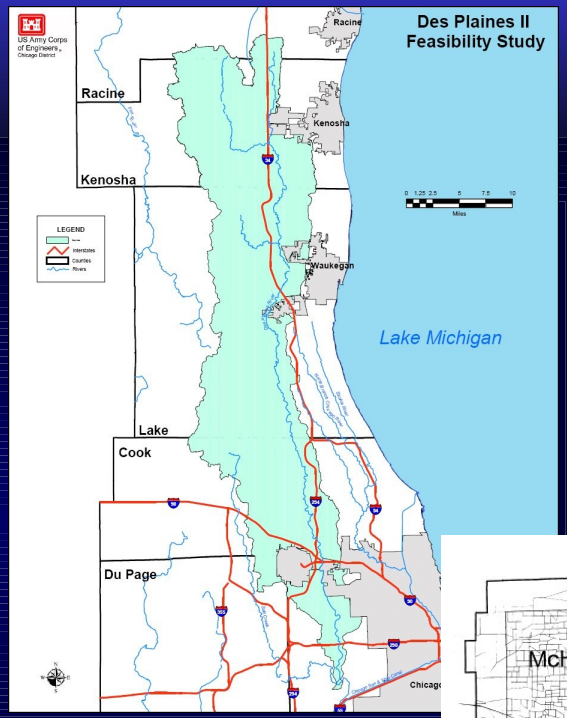


Figure 7.1 Embankment-Pavement Losses

Based on highway sections 48 feet wide, 40 feet of asphalt pavement, well vegetated 3 to 1 side slopes, and sandy-clay fill material.

Analysis of Traffic Delays From Flooding, Des Plaines River Watershed Study, David Boyce, UIC, 2002

- Existing network (40,000 links) and traffic demands
  - Chicago Area Transportation Study, CATS
  - Traffic during 4 time periods during 24-hour weekday (1996, 2020)
- Road Segment Closures
  - Base, 5, 10, 25, 50, 100, 500 year return floods
  - Maximum 196 links (235.4 miles) closed for 500 year flood
  - Flood proofing individual crossings
  - Info provided by Corps



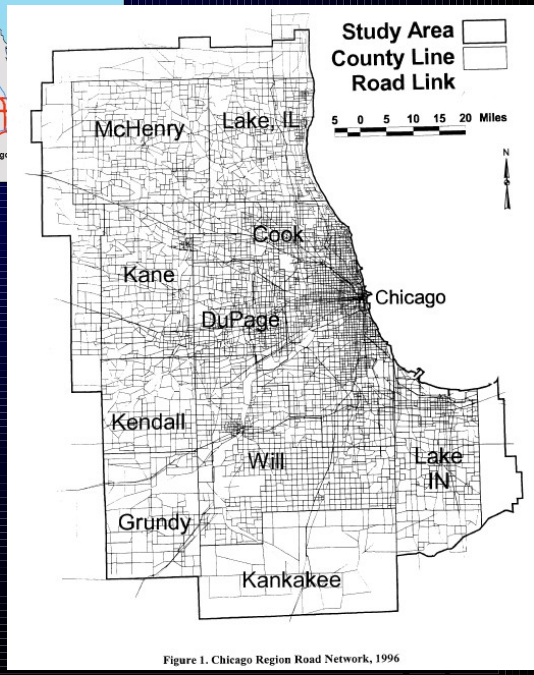
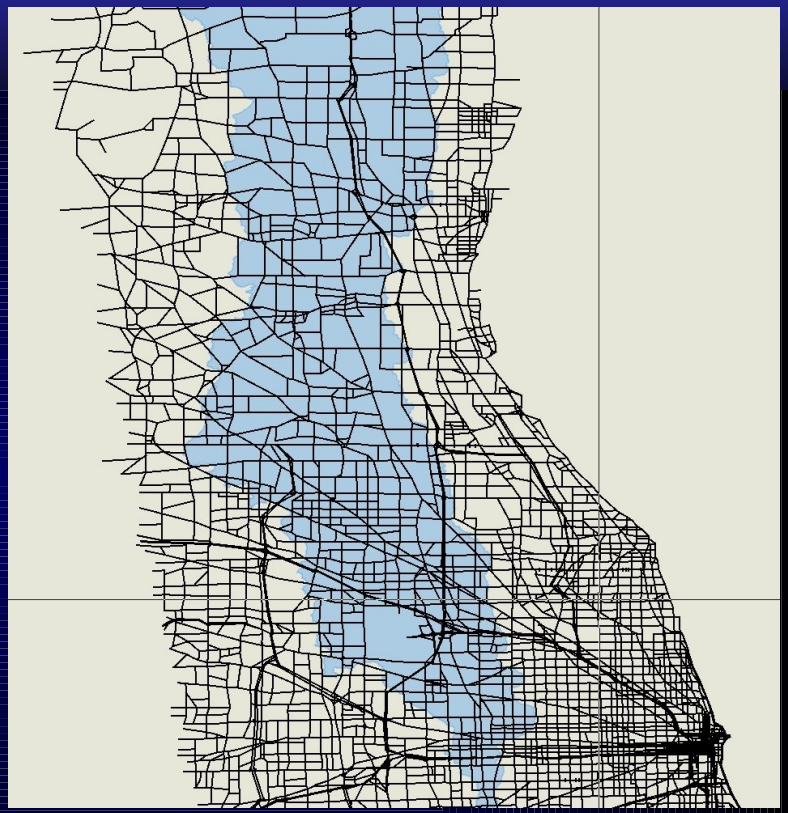


Figure 1. Chicago Region Road Network, 1996

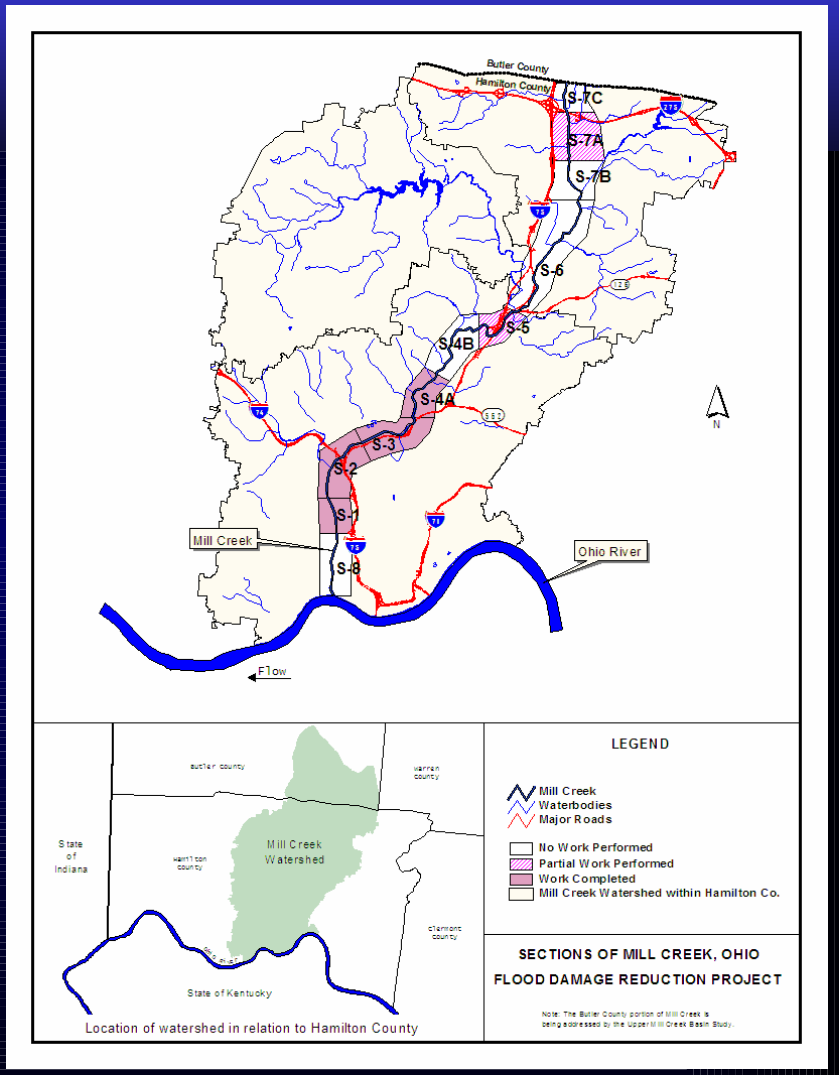
Des Plaines Watershed, Ziliaskopoulos, Northwestern, 2005

- For Chicago District
- Same Problem, Different Model
  - Dynamic Traffic Assignment (DTA)
    - Traffic flow dynamics
    - Individual driver decisions and paths
    - Iterative process
    - Compute-intensive???
  - Visual Interactive System for Transportation Algorithms (VISTA)



Mill Creek, Ohio (Cincinnati), flood damage reduction project, 2005

- Louisville District
- VISTA Traffic Model
  - Local network, demand data (presumably OKI)
- Impact of flooding on traffic
  - WO project condition
    - traffic delay cost
  - Automated Gates
    - False closure 4/yr
  - Other alternatives



Design Document Recommendations: Near Term (remainder of 2008)

- Develop modeling techniques on test beds
  - Worked examples
  - Define data structures
  - Spreadsheet for data organization
- Strawman damage functions
  - How to organize?
  - Damage-driving parameters?
  - Based on existing techniques
    - BMA Statistical (direction, velocity)
    - HEC-17 (depth, duration)
- Look for more data to support damage functions
  - State data collection programs

Design Document Recommendations: Medium Term

- Incorporate road network analysis capabilities into HEC-FIA 2.1 (GIS version)
- FIA: Single Event Economic Analysis
  - Uses external hydraulic models
- Already Implements:
  - Agricultural (time-based)
  - Structural Damages
  - Loss of Life (simplified) to be added

Issues: Road Network Data

- Data base format for road network segment physical characteristics
- Sources of road data
- Special Representation for high value structures (e.g. bridges)
  - Longer Repair Time / Higher Priority
  - Damage Functions?

Issues: Transportation Data and Models

- Existing Model Availability for a study area?
- What to do if no model available?
- Sources of transportation data
  - Trip demands / Large area road networks
- Who should do modeling?
- Spatial extent of analysis?
- Complexity of modeling
  - Route choice only?
  - Trip Demand / Mode Choice affected?
  - Static vs. Dynamic Traffic Assignment?
- Cost of Modeling
- Commercial vs. Non-Commercial Models

Questions for the Field

- Desirability of “Standardized” Approach?
- Cost Elements To Be Included?
  - Segment-level
  - System-level
- What is Appropriate Level of Analysis / Nature of Tools?
  - Spreadsheet
  - Models
  - GIS Framework
- Expectations for Data / Modeling Availability?
  - Damage Estimation Capability
  - Road Network Information
  - Transportation Model
- Coastal vs. Riverine Flooding Applications?

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